at high-energy are therefore particularly appealing for cosmological studies based on the halo mass function (e.g. Borgani et al. 1999; Reiprich & Böhringer 2002; Henry et al. 2009; Mantz et al. 2010; Ilić, Blanchard & Douspis 2015; Böhringer, Chon & Fukugita 2017; Schellenberger & Reiprich 2017; Pacaud et al. 2018). Definitive assessment of the nature of the emitting sources, including a precise measurement of their redshifts, is provided by the 3D association with their member galaxies, which is achieved in the most robust manner through spectroscopic redshift surveys in the optical domain. These allow measurements at a precision far below the typical velocity dispersions of their host haloes.

Collecting large numbers of spectra of candidate member galaxies is an observational challenge requiring highly multiplexed, wide-aperture instrumentation supported by high-quality uniform photometric surveys to draw targets from. The SPIDERS (SPectroscopic IDentification of eROSITA Sources) programme within SDSS-IV (Blanton et al. 2017) addresses this need in the context of wide-area X-ray surveys. Sharing survey strategies with an observational cosmology project (the extended Baryon Oscillation Survey eBOSS; Dawson et al. 2016) makes possible the acquisition of a large number of spectroscopic redshifts for objects identified as counterparts of X-ray emitting sources. The main challenge resides in ensuring maximal completeness and wide uniformity of the data sets.

X-ray sources found outside of the Galactic plane can be divided into several categories: galaxy clusters, active galactic nuclei (AGNs), X-ray emitting stars, compact objects, etc. (e.g. Voges et al. 1999; Evans et al. 2010; Rosen et al. 2016). Each class of object requires its own strategy in order to target the most likely optical counterpart, given the limited positional accuracies, depths, spectral resolution, etc. Numerous AGN candidates found as point-like sources in the Röntgen Satellite All-Sky Survey (RASS; Truemper 1993) and the *XMM–Newton* Slew survey (Saxton et al. 2008) require maximum-likelihood or bayesian methods to enhance the chances of association with an infrared or optical AGN (Dwelly et al. 2017). Clusters of galaxies are scarcer and they possess extended morphologies on the X-ray sky; however it is difficult to distinguish an extended source from a point source below a certain flux level and beyond the instrumental angular resolution limit. The 'red sequence' (e.g. Gladders & Yee 2000), formed by passive galaxies in those massive haloes, helps to characterize them. Multiband photometry of these galaxies provides an estimate of their redshift (e.g. by locating the 4000 Å break passing through filter passbands). This is the strategy adopted in SPIDERS for selecting clusters: two X-ray samples extracted from the RASS and the *XMM–Newton* archive are searched for optical red sequences in SDSS DR8 photometry (Aihara et al. 2011) using the redMaPPer algorithm (Rykoff et al. 2014).

A description of the parent SPIDERS galaxy cluster samples and targeting strategies is provided in Clerc et al. (2016) (hereafter C16). The target list was publicly released alongside SDSS Data Release 13 (DR13; Albareti et al. 2017) in the form of a Value-Added Catalogue[1] (VAC). C16 additionally describes the construction of an X-ray selected galaxy cluster sample using spectroscopic data from a pilot survey located in a sub-area of sky covering 300 deg^2 (see Alam et al. 2015, for a description of the spectroscopic data set). This work demonstrated the end-to-end feasibility of the SPIDERS project; the final catalogue of 230 systems is available as a VAC. This VAC highlighted key features of the sample, including its coverage of the mass-redshift plane and the availability of velocity dispersions.

[1]All VACs are accessible under this link https://www.sdss.org/dr16/data_access/value-added-catalogs/

An updated catalogue of 520 systems with high optical richnesses was released in the form of a VAC as part of DR14 (Abolfathi et al. 2018) with a corresponding sky area of about 2500 deg^2. The DR14 catalogue forms the basis of studies on the richness–mass and luminosity–mass relations (Capasso et al. 2019, 2020) and on properties of Brightest Cluster Galaxies (Furnell et al. 2018; Erfanianfar et al. 2019).

This paper enlarges the scope of the survey and directly relates to DR16 (Ahumada et al. 2020). This data release contains the entire set of SPIDERS spectra. The motivation of this paper is to provide a detailed census of the data collected in the course of the project, to describe the various steps that led to the final catalogues and to expose salient features in the data, which includes a discussion on the statistical content of the galaxy cluster sample.

The outline of this paper is as follows. Section 2 describes the SPIDERS survey design, the updated targeting strategies, and the sensitivities of the relevant components. Section 3 provides a detailed assessment of the content of the DR16 spectroscopic data relevant to SPIDERS galaxy clusters. Section 4 discusses the adopted survey strategy, and we provide prospects for future massively multiplexed follow-up programmes. Unless otherwise stated, the cosmological model used in this paper is flat Cold Dark Matter with $\Omega_m = 0.3$ and $H_0 = 70$ km s^{-1} Mpc^{-1}. Magnitudes are expressed in their native SDSS (AB) system (Fukugita et al. 1996).

2 THE GALAXY CLUSTER SURVEY

This section is an overview of the survey design and targeting strategies. We also describe the galaxy cluster selection function prior to spectroscopic observations.

2.1 Parent samples and target selection

We refer the reader to C16 for an in-depth introduction to the CODEX and X-CLASS parent samples and the algorithms applied to select targets in optical imaging data. These targets are astronomical sources identified in photometric catalogues, a vast majority of them are galaxies. Fig. 1 displays the area on the sky relevant to this section; i.e. the 'chunks' eboss1-5, 9, 16, 20, 24, 26, 27 and SEQUELS (boss214, 217) where we effectively selected the targets relevant for the programme and acquired data throughout the survey. All targets described in this section have a target bit mask EBOSS_TARGET1 set to 31 in SDSS products; a few target subclasses were defined described in the following paragraphs.

2.1.1 The CODEX sample and targeting

CODEX is a search for faint, X-ray extended sources in all-sky *ROSAT* data (RASS), coupling a wavelet algorithm to an automated optical cluster finder in the BOSS 10 000 deg^2 *ugriz* imaging area (Finoguenov et al. 2020). Specifically, two different X-ray source catalogues were produced by varying the wavelet threshold and the region of each significant source was searched for an optical counterpart (red-sequence) using the REDMAPPER software (Rykoff et al. 2012, 2014). The two catalogues were then cross-matched and duplicates were eliminated.

The optical finder provides an estimate for the photometric redshift, z_λ, of the galaxy cluster – mainly based on the colours of the passive galaxies forming the detected red-sequence – and an optimized richness estimator, which scales with the number of galaxies exceeding a threshold stellar luminosity. Because of the

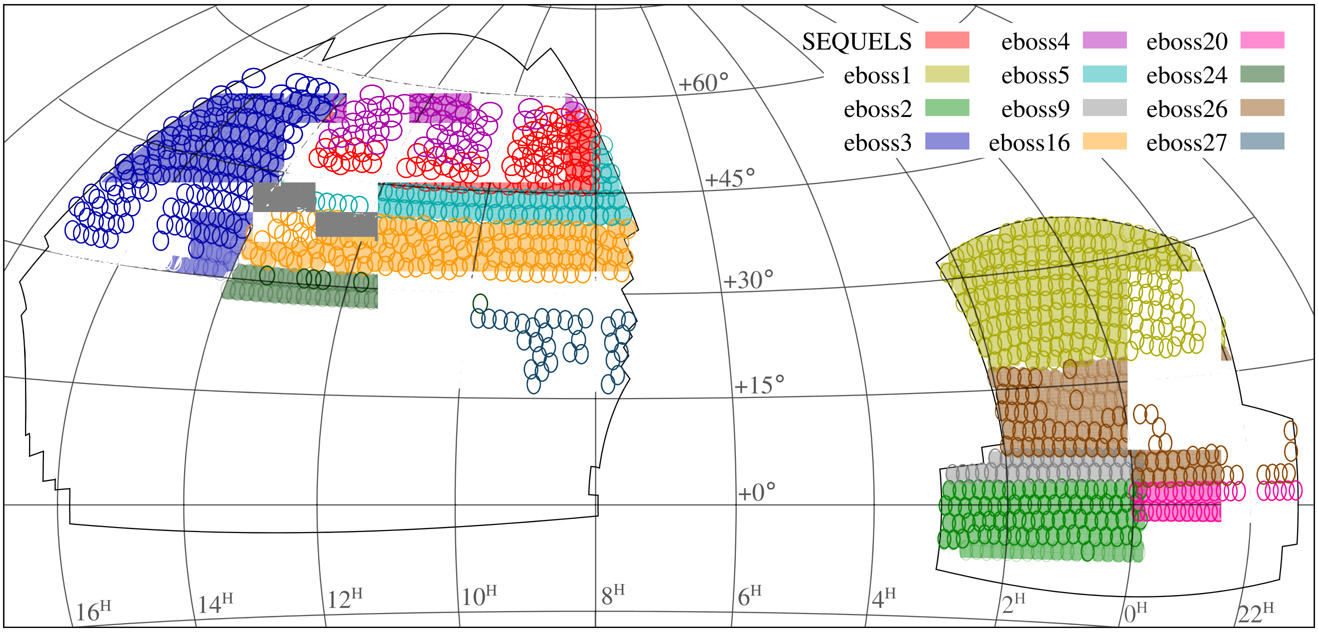

Figure 1. Location of the survey in equatorial coordinates – this figure updates Fig. 1 in C16. The thin black contour delineates the BOSS optical imaging area. The various chunks are tiled separately according to target selection algorithms. Chunks with at least one observed plate relevant to the SPIDERS survey are displayed on this figure with colours; they define the SPIDERS targeting area. Circles with a diameter of 3° represent individual spectroscopic plates. Those outlined with a heavier stroke have average spectral signal-to-noise ratios passing eBOSS requirements (1000 fibres each, shared between SEQUELS, eBOSS, TDSS, SPIDERS) and define the SPIDERS DR16 survey area.

relatively large uncertainty in the RASS source positions, reaching up to a few arcmin for extended sources, the constraint on the centre is relaxed and the algorithm optimally finds an optical centre within 3 arcmin of the X-ray position. Refined estimates for the cluster photometric redshift and richness, dubbed 'OPT' (optical), are calculated using the new position.

A critical by-product of this procedure is a list of identified red-sequence members, each assigned a membership probability $p_{mem} \in$ [0, 1]. This ranked list of probabilities, attached to each candidate X-ray selected cluster, forms the basis of the targeting strategy and confirmation process (C16).

As explained in C16, chunk eboss3 benefits from a slightly modified targeting scheme due to the higher density of X-ray sources in this area of sky. This scheme effectively favours confirmation of many low-mass systems at the expense of a lower number of members per individual cluster (Section 3.5).

In chunk eboss20 we added red-sequence targets at larger cluster-centric radii than usual (up to five times the virial radius) in order to enable cluster mass determination through the caustic method (Diaferio 1999). A few clusters were selected to this end, specifically weak-lensing detected clusters in the CFHT/Stripe82 imaging survey (Shan et al. 2014) with a match in the CODEX catalogue. Fig. 2 shows the distribution of targets on sky.

All targets described so far have bit mask EBOSS_TARGET2 set to 1.

A few improvements to the target selection were adopted, mainly intended to help confirm high-redshift systems in chunks eboss26 and eboss27. The following additional targets take advantage of deeper optical data sets overlapping the CODEX sample:

(i) SPIDERS_CODEX_CLUS_CFHT: following the procedures described in Brimioulle et al. (2013), pointed CFHT/Megacam observations and CFHT-LS fields provide deep $ugriz$ photometry.

Figure 2. SPIDERS galaxy cluster targets locations in chunk eboss20. This is an expanded view at R.A. 23h and Dec 0° in Fig. 1. The red circles have radii five times the virial radius of each cluster detected in CODEX and CFHT lensing maps in Stripe82. Photometric members are indicated in light grey; targets indicated as dark blue dots were assigned a spectroscopic fibre.

The REDMAPPER (Rykoff et al. 2014) cluster finder detected 598 red-sequence galaxies selected as targets. Among them 515 are new additions to the original list of targets, thereby increasing by about one magnitude the depth probed in the small area of the sky covered by CFHT observations. The corresponding target bit mask EBOSS_TARGET2 is 6.

(ii) SPIDERS_CODEX_CLUS_PS1: a few high-redshift ($z > 0.5$) CODEX cluster candidates were searched for red-sequence counterparts in PanStarrs PS1 (Flewelling et al. 2016). Our custom version of the Multi-Component Matched Filter (MCMF) tool (Klein et al. 2018) imposes a radial constraint of 2 Mpc for members based on the REDMAPPER centre. Within this radial cut, each source is assigned a distance in colour-space ($g - r$, $r - i$, and $i - z$) to a red-sequence model. Each source's colour-distance is transformed into a colour-weight in every colour, which is then convolved with a Gaussian smoothing kernel to provide an estimate of the local density of red-sequence galaxies in the region of the cluster candidate. A total